Aviation Safety Program

System-Wide Accident Prevention

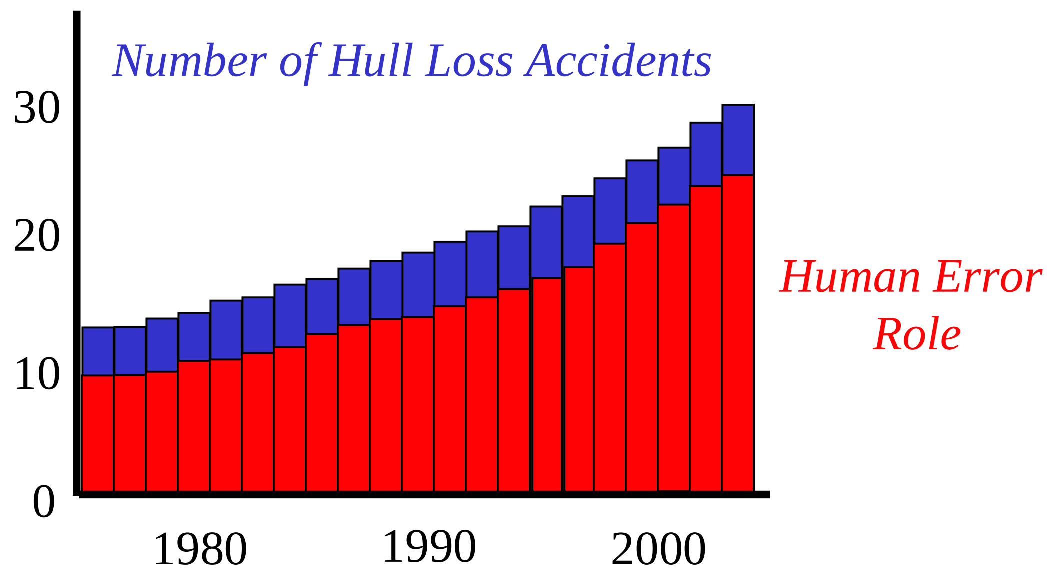
Dr. Tina Beard

Investigation Methods and Tools Workshop

NASA Ames Research Center

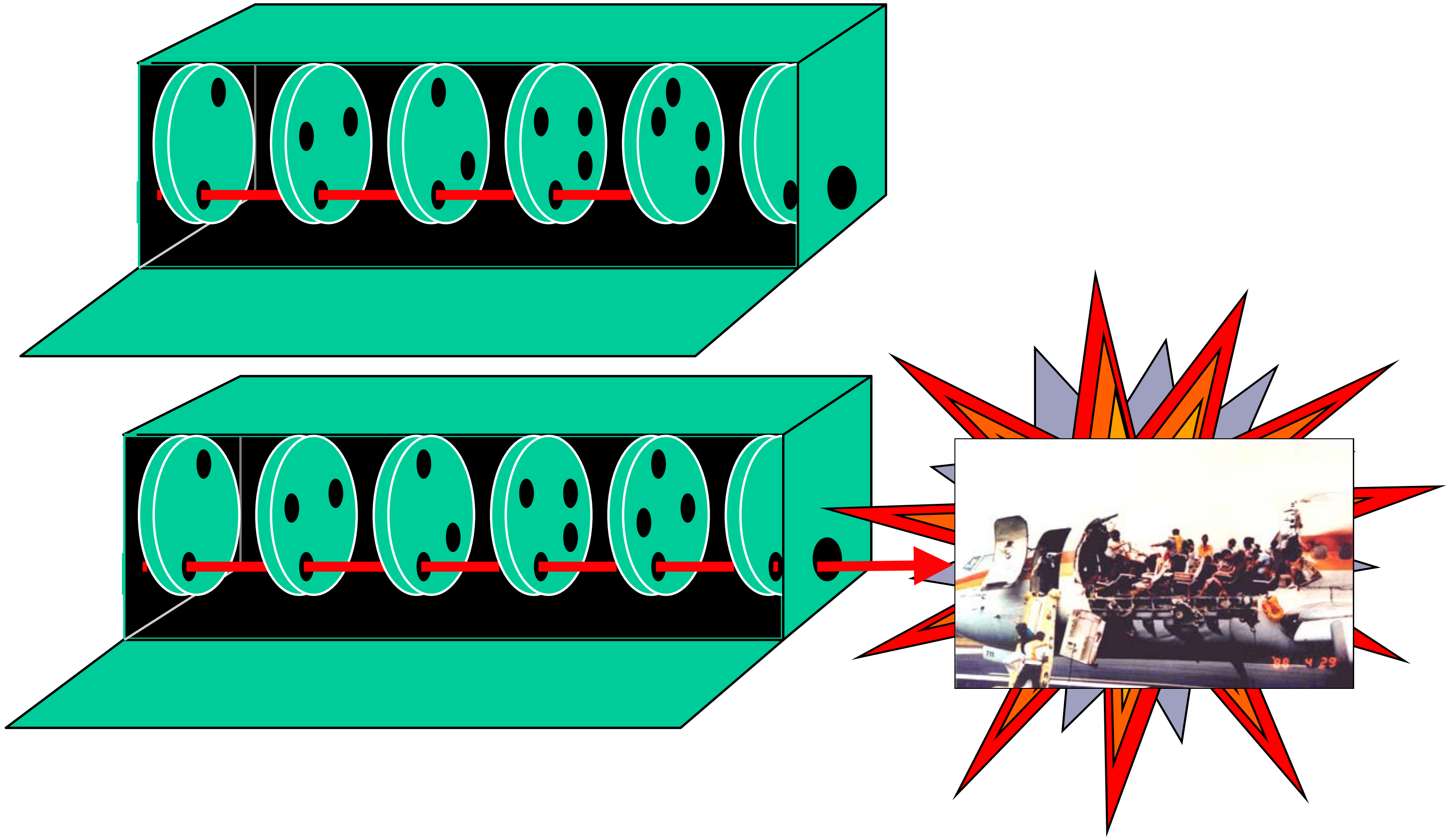
July 31, 2003

Human Error Role in Aviation Accidents



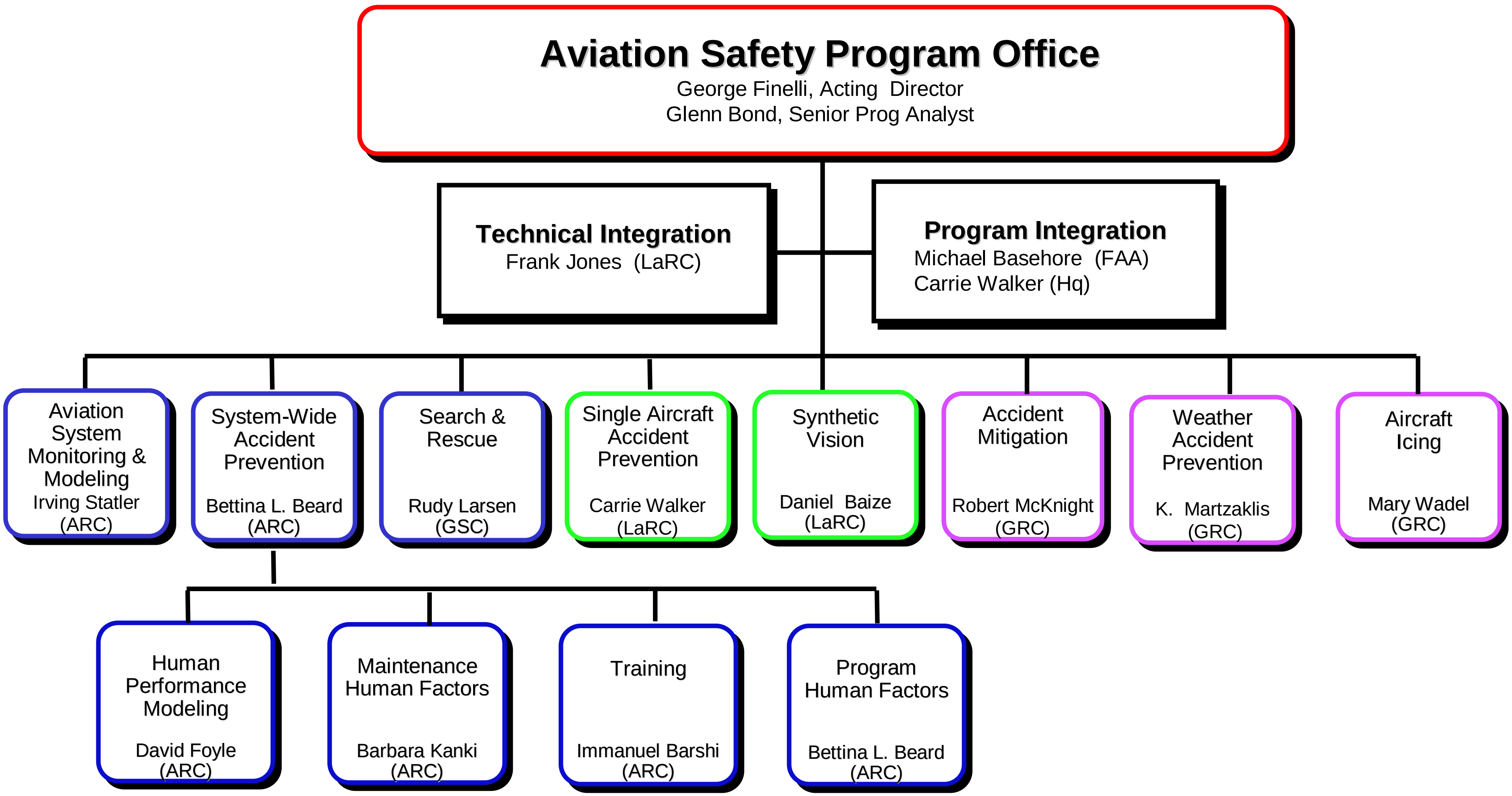
- Number of hull loss accidents has steadily increased over the past 25 years
- Human factors issues have steadily accounted for ~70% of these accidents
- Introduction of new technological devices or procedures
- Trading one source of human error for another

Problem

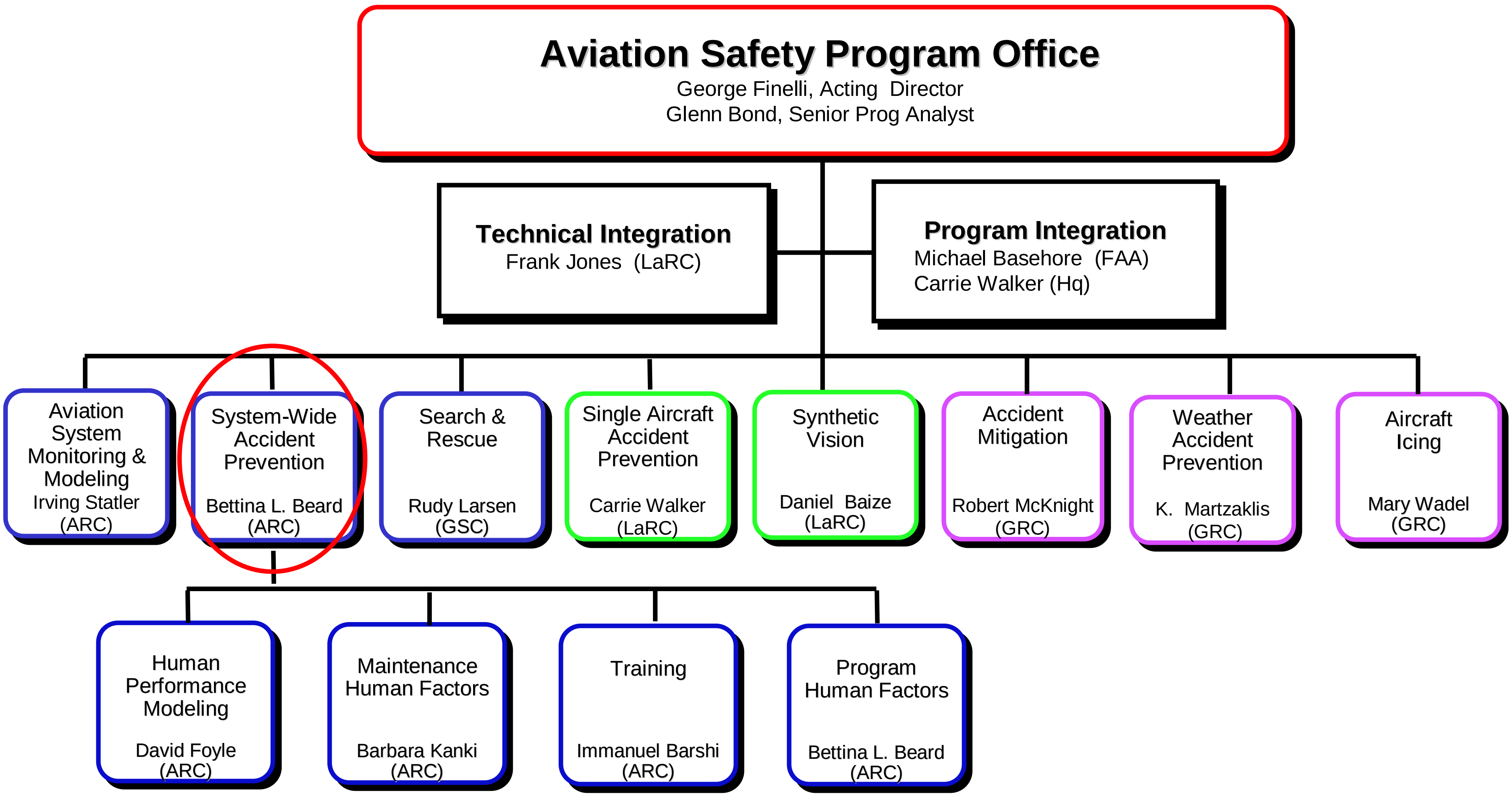


- Accidents result from a chain of events
- Many distinct human error related causes of aviation accidents, due to behavior of both air and ground crew
- Degree that each of these precursors contributes to accidents varies over time

Current AvSP Program Organization

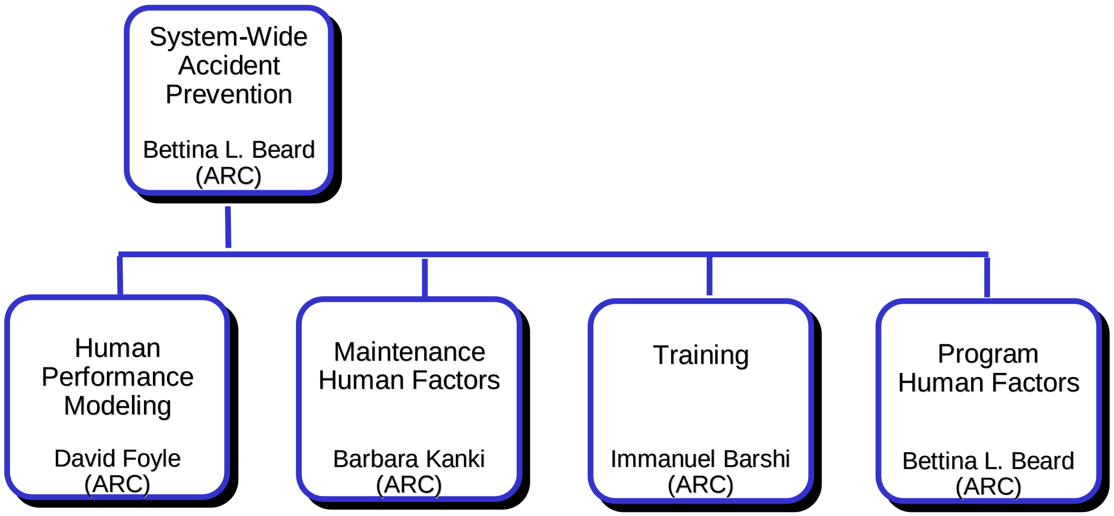


Current AvSP Program Organization

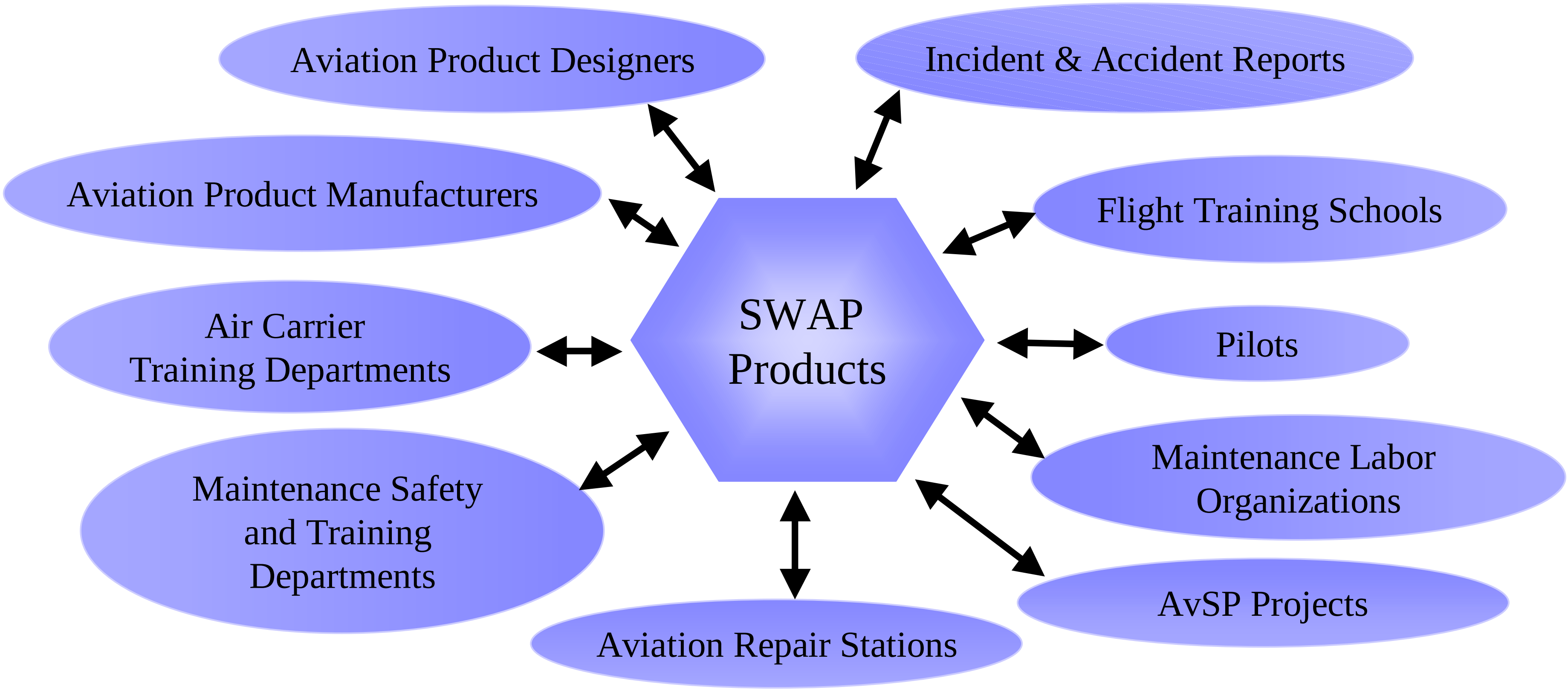


SWAP Project

- SWAP uses current knowledge about human cognition to develop mitigation strategies to address current trends in accident and incident profiles
- Develop and provide guidelines, recommendations & tools directly to customers through --
    - Better understanding of human error and human reliability associated with tasks
    - Development of interventions and task aids that reduce human error and enhance safety and effectiveness



Active SWAP Customers



Continuous involvement of operational partners through all phases

- Identification of human errors
- Definition of HF requirements and risks
- Development of techniques & tools; HF interventions
- Operational validation & implementation

Helps with user acceptance

Establishes a clear transition path to industry implementation

Approach

4. Validate PRODUCTS

Field Tests

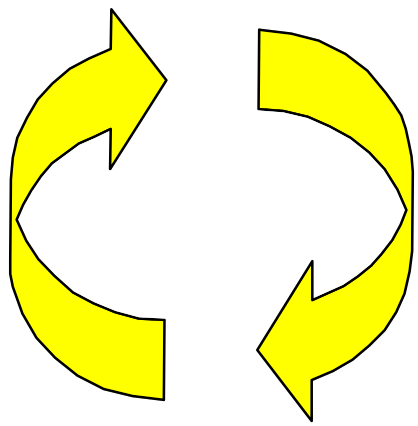
Accident & Incident Analysis

ASRS

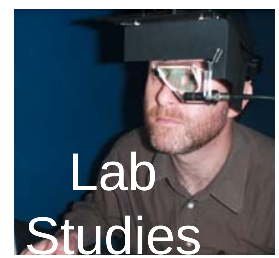
1. Identify SAFETY NEEDS

Aviation Research

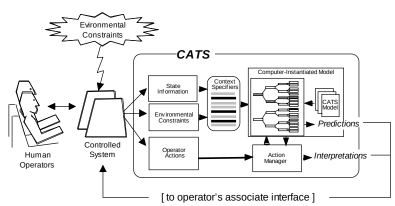
Literature Reviews



- **Consult with subject matter experts**
- **Scientists are rated pilots**



Part-task & Full Mission Simulations



Computational Modeling

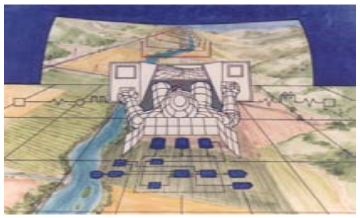
Field Observation Data

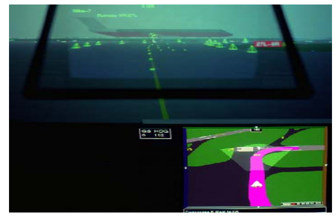
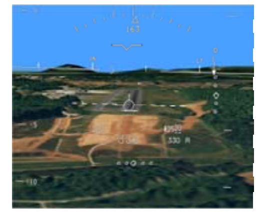
2. Apply METHODS, TOOLS

3. Develop INTERVENTIONS

HPM Products

Aviation Safety Program — **SWAP**




Human Performance Models
Crew Activity Tracking

System-Wide Accident Prevention
Bettina L. Beard (ARC)

- Human Performance Modeling — David Foyle (ARC)
- Maintenance Human Factors — Barbara Kanki (ARC)
- Training — Immanuel Barshi (ARC)
- Program Human Factors — Bettina L. Beard (ARC)

Selected Modeling Frameworks

Characteristics of selected models

- **Operator level, cognitively oriented**
- **Comprehensive, mature and validated systems**
- **Integrative frameworks facilitating fast-time simulation**
- **Output is generative, stochastic, context sensitive**

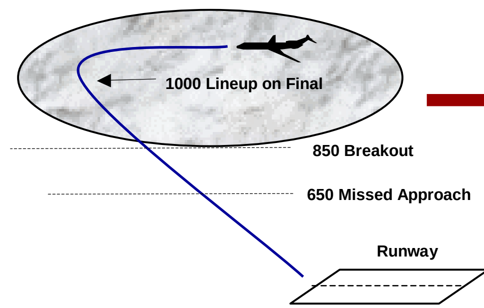
Model	*Type*	*Research Team*	*Demonstrated Sources of Pilot Error*
ACT-R/PM	Low-level Cognitive with Statistical Environment Representation	Mike Byrne Rice University Alex Kirlik University of Illinois	* Time pressure * Misplaced expectations * Memory retrieval problems
Air MIDAS	Integrative Multi-component Cognitive	Kevin Corker Brian Gore Eromi Guneratne Amit Jadhav & Savita Verma San Jose State University	* Workload * Memory Interference * Misperception *Multi-crew Communication
A-SA	Component Model of Attention & Situational Awareness	Chris Wickens Jason McCarley Lisa Thomas University of Illinois	* Misplaced attention * Lowered SA
D-OMAR	Integrative Multi-component Cognitive	Stephen Deutsch Richard Pew BBN Technologies	* Communications errors * Interruption & distraction * Misplaced expectation
IMPRINT/ ACT-R	Hybrid: Task Network with Low-level Cognitive	Rick Archer Micro Analysis and Design, Inc. Christian Lebiere, Dan Schunk,& Eric Biefeld Carnegie Mellon University	* Time pressure * Perceptual errors * Memory retrieval * Inadequate knowledge

Progressive Implementation Strategy

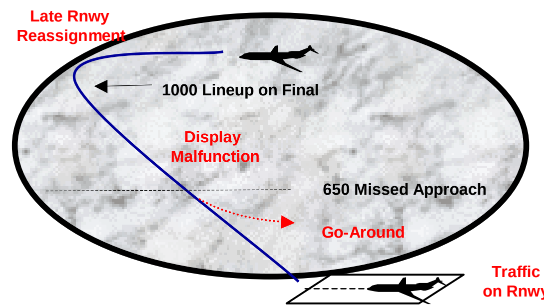
Advancing cognitive models into increasingly complex real-world applications

'01 Modeling Taxi-Navigation Errors

'02-'03 Modeling Nominal Approach/Landing with and without SVS



'03-'05 Modeling Multiple Off-Nominal Approach/Landing with and without SVS



Taxi Navigation Modeling

Data Set

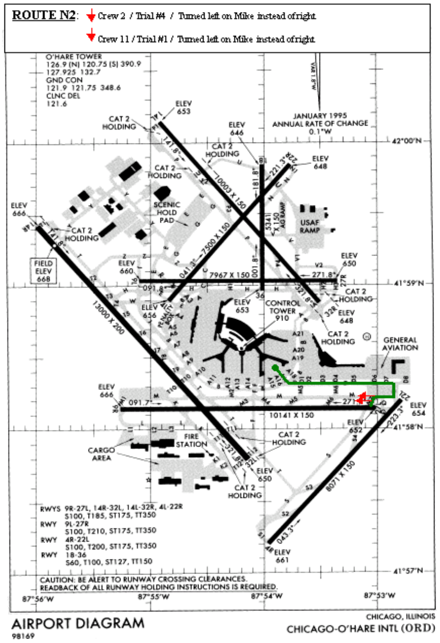
T-NASA Full Mission Simulation

Modeling Problem

Reproduce/Explain
Taxiway Navigation Errors

Scenario Specifications

- **High-fidelity full motion simulation of taxi-to-gate at Chicago-O'Hare**
- **54 trials run by 18 airline crews**
- **9 different cleared routes -- all in low visibility (1000 RVR)**
- **Traffic, hold short, and route changes included in scenarios**
- **12 off-route errors committed by crews and specified to modelers**



Air MIDAS Simulation of Observed Error

ERROR

Fixate, Control input stop ac communicate
Fixate, communication, monitor progress
Monitoring, communicating with supervisor

Fixate, Control input Stop Aircraft, prepare for right turn
Fixate, communication, consult clearance
CONFIRMATION BIAS EXERCISED
monitoring

Fixate, Control input turn and increase speed
Fixate, communication, monitor progress
monitoring

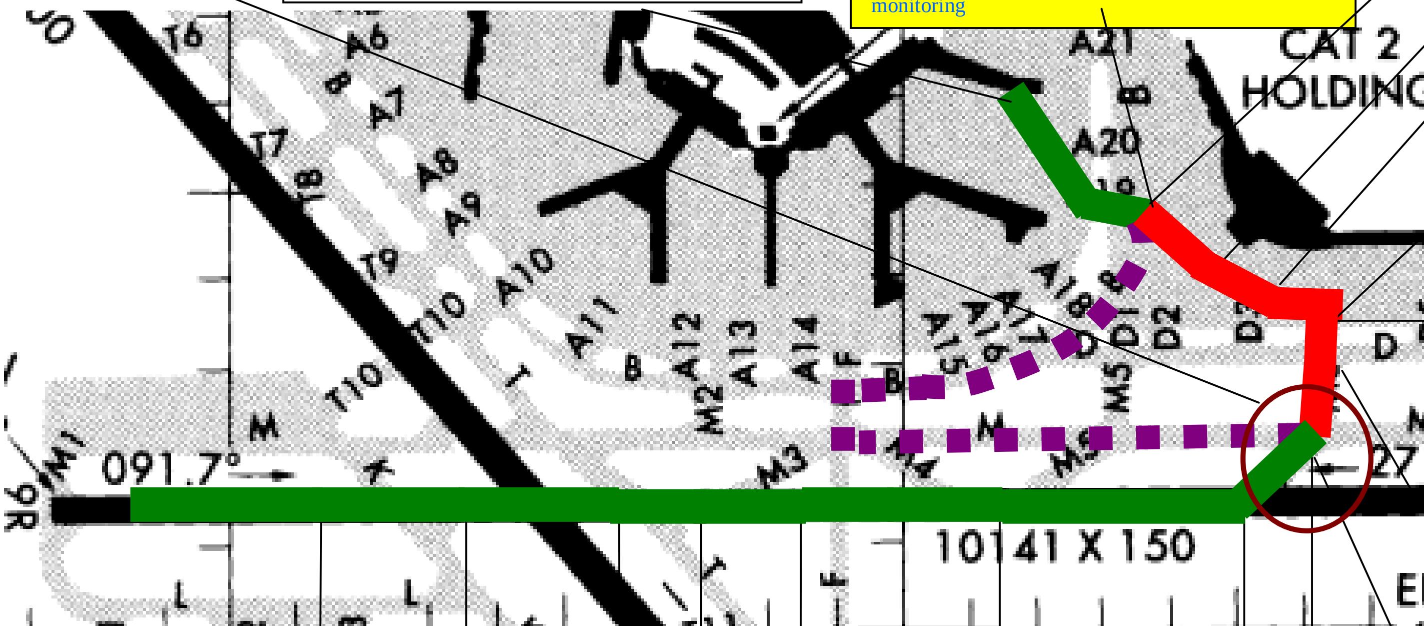
Monitoring Control input, turn aircraft
scanning, communication
monitoring

Monitoring Control input
scanning, communication
monitoring

Monitoring Control input (accelerate, time delay, stress, DIRECT LINE TO GATE
scanning, communication lost SA
Monitoring, communicating

Monitoring Control input, increased communication
scanning,increased communication, lost SA
CONTACT TOWER
Monitoring, decision process

Fixate, Control input accelerate
Fixate, communication communication monitoring



Captain

First Officer

ATC

Monitoring (Roll out, autobrake) Control input (switch alarm off, disarm auto)
verifies thrust levers, monitor ground speed,& communication (speed and sign call out)
communication monitoring

Monitoring (Roll out, autobrake), hearing, Control input (brake)
monitor speed, communication (speed and sign call out)
Monitoring

Monitoring Control input
scanning, communication
communication monitoring

Monitoring Control input
scanning, communication
communication monitoring

Monitoring Control input
scanning, communication(signage/speed call out)
communication monitoring

Monitoring Control input
scanning, communication
communication monitoring

Monitoring Control input, SA verification
scanning, communication (sign-/speed monitoring)
communication monitoring

Monitoring Control input
scanning, communication
communication monitoring

Fixate, Control input Wait for clearance
Fixate, communication, hear/write clearance, clean up procedure
communication monitoring

Fixate internal, Control input (AC control), Cognitively missed signage
Clean up head down, Fixate, communication, hear/write clearance , communication and navigation
DECLARATIVE INFORMATION LOSS THROUGH INTERFERERENCE
communication monitoring

Modeling Nominal Approach & Landing

Data Set

Part-task Pilot-in-loop Simulation
Performance data and Eye-tracking (3 Subjects)

Other Information Provided Modelers

Detailed Cognitive Task Analysis

Modeling Problem

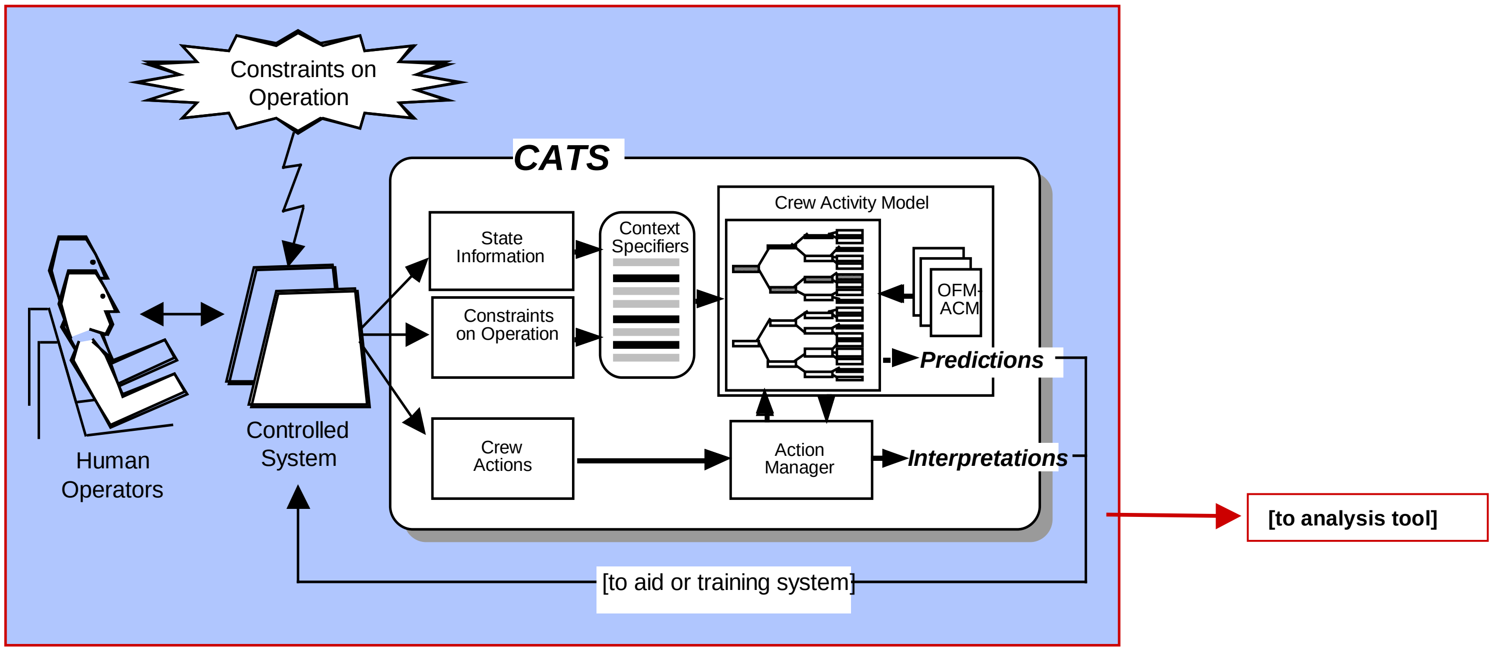
Develop "Normative" Model of Approach & Landing with and without Augmented Display

Scenarios

Display Configuration	Baseline	Baseline	SVS
Visibility	VMC	IMC	IMC
Nominal Approach (nominal landing)	*Scenario #1*	*Scenario #4*	*Scenario #7*
Late Reassignment (side-step & land)	*Scenario #2*		*Scenario #8*
Missed Approach (go-around)	*Scenario #3*	*Scenario #5*	*Scenario #9*
Terrain Mismatch (go-around)		*Scenario #6*	*Scenario #10*

Crew Activity Tracking System (CATS)

- Computerized engineering model of correct task performance to predict operator activities and interpret operator actions



- **Provides context-dependent knowledge about the operator’s task that can support tutors, aids, and displays to enhance safety**
- **Supports visualization and analysis of human-automation interaction**

Detecting Errors from Flight Data

Current research demonstrates how CATS can analyze flight data from the Langley B757 ARIES aircraft to detect procedural errors

Callantine (2001a, 2001b)

NASA B757-ARIES

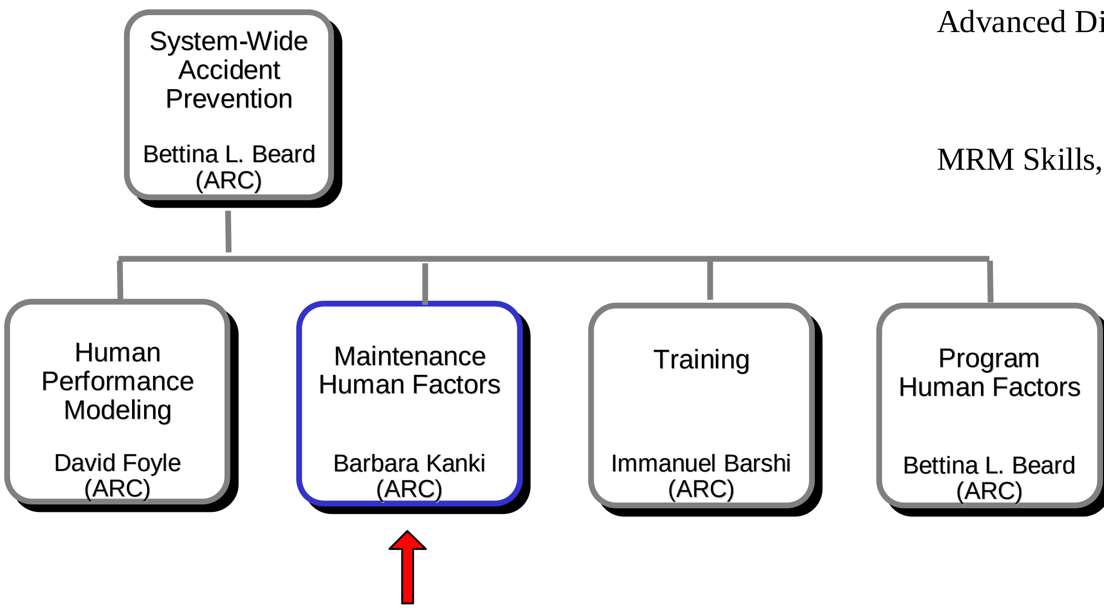
On-board Data Acquisition System used to collect flight data

Cockpit observations verified and augmented digital data

MHF Products




Maintenance Error Baselines
  Inhouse: Crew Factors Group
HF Risk Analysis Tools
  University of Idaho
Advanced Displays (VR & AR)
  Clemson University
  Boeing, Huntington Beach
MRM Skills, Training & Evaluation
  Santa Clara University
  Naval Postgraduate School & Navy Safety Center



Maintenance Error Baselines

- GOAL: Establish current maintenance error baselines in order to identify safety needs. Re-visit the NASA ASRS database in response to a significant increase in ASRS reporting.
  - ~200 reports during 1993-1998
  - ~800 reports during 1999-2000

- OBJECTIVES
  - Update ASRS incident summaries applying various typologies
    - MEDA (Boeing): Emphasis on procedural errors (~44%) and related factors (e.g., the document itself, time constraints, insufficient technical support)
    - HFACS-ME: Focus on context, management, maintainer & workplace conditions

- TOOLS: A standard relational database for future analyses supporting
  - multiple coding strategies
  - direct links from one set of analyses to another
  - data transformations required for text analysis of narratives (QUORUM/PERILOG)

- STUDIES IN PROGRESS
  - Analysis of procedural errors
  - Shift handover
  - MEL document
  - MX log
  - Time pressure
  - Relationship between error types and preconditions

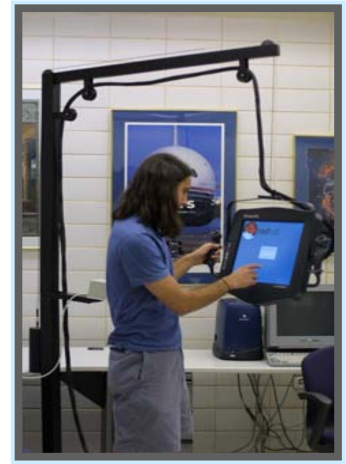
San Jose State Univ Fndn – Battelle, ASRS
Partner: ATA MHF subcommittee, ASAP operators

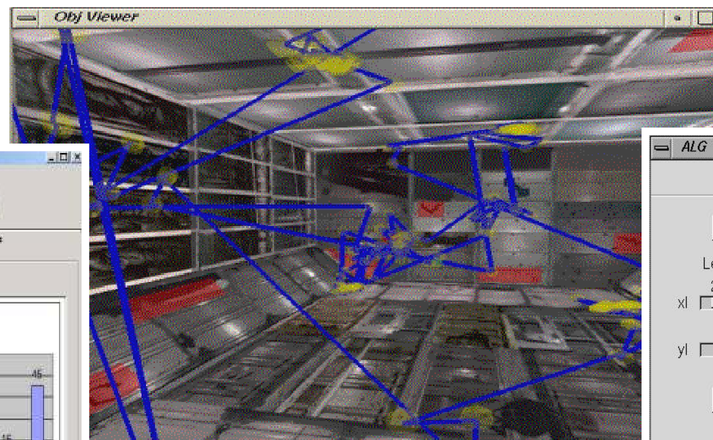
Advanced Displays: Virtual Reality

- GOAL: Develop technologies that augment traditional OJT and aid tasks through enhanced information support
- APPROACH: Virtual Reality (VR) simulator for A/C visual inspection training and for controlled studies of human performance
- PRODUCTS to date
  - VR simulation of aft cargo bay, fuselage, wing with potential defects.
  - 3D eye movement analysis algorithm for collecting eye movement data.
  - Experimental protocol for conducting studies related to the use of feedback and feedforward for inspection training.

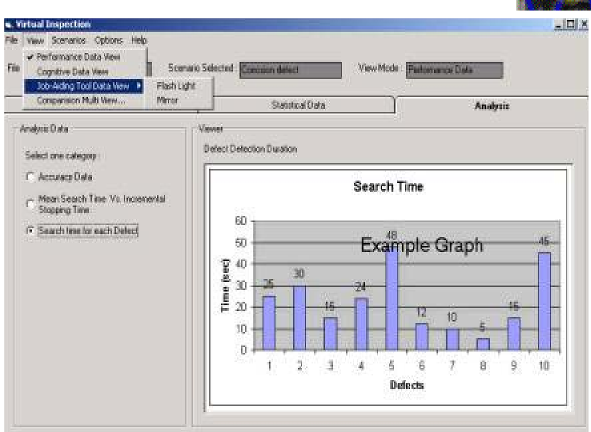
- CURRENT STATUS
  - Tested, verified, and validated performance and process (cognitive measures) data collected by the simulator.
  - Developed GUI for presenting feedforward and feedback data on process and performance measures (output measures).
  - Developed scenarios for conducting studies using data collected from industry partners
- Partners
  - DAL, Fed Ex, Lockheed Martin Aircraft Centers, NASA KSC
- NEXT
  - Experiment evaluating various inspection training methods
  - Focus on collaborative OJT

VR Simulation Tools

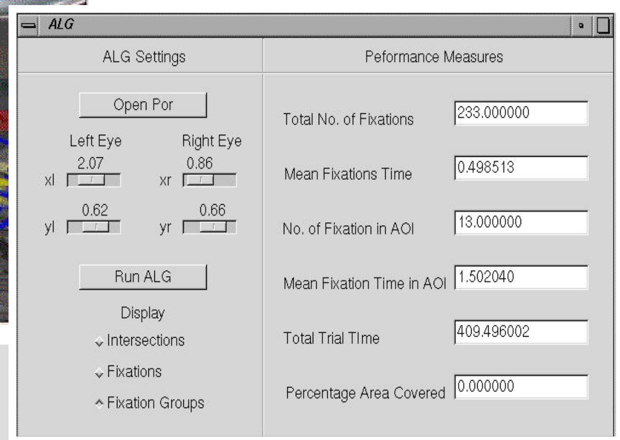




A 3D display for providing graphical cognitive feedback information



Summary of performance data



Interface provides statistical cognitive feedback information

Performance and Process feedback in the VR environment

Advanced Displays: Augmented Reality

- GOAL: Measurement of process improvement achieved when real-time collaboration is supported by an image-based technology

- APPROACH
  - Definition and selection of an implementation testbed (field site plus engineering site)
  - Implementation of devices and processes for collaboration
  - Measurement of system performance used to gauge the effectiveness of the process improvement to the targeted collaboration.

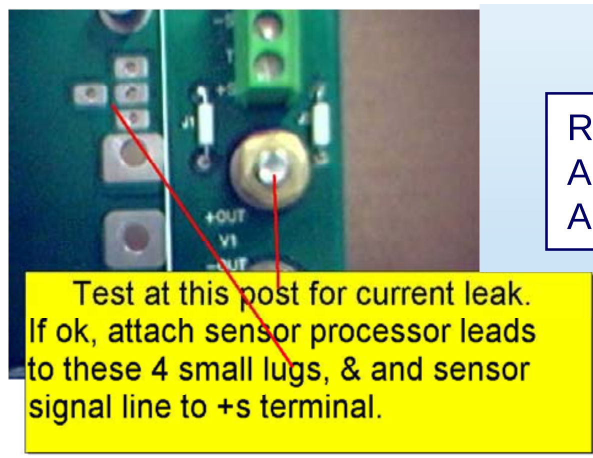
- PRODUCT Benefits
  - Efficient guidance for uncommon tasks.
  - Complement training / compensate for compressed training schedule.
  - Reduce cost of engineering resolutions.
  - Provide views for areas of limited access.
  - Reduce time away from worksite.
  - Provide access to multiple sources of information.
  - Synergy with multiple contributions to a solution.
  - Markup on imagery may be customized for the technician

Anthony Majoras, Boeing, Huntington Beach
Potential Partners: USAF C17

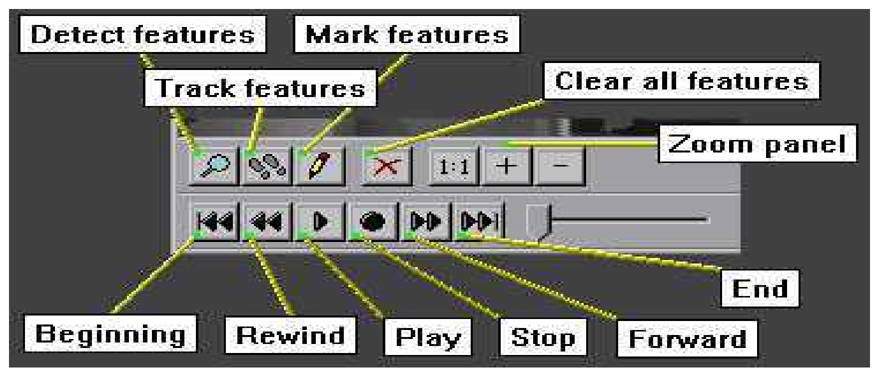
BOEING ®

Advanced Displays: Augmented Reality: Collaborative Engineering Support Tool

Prospective Environments



Remote Collaboration and Annotated Images:
A Problem-Solving System



Instructions via Annotated Video
VCR-like interface for tracking software
(Neumann & Majoros, 1998)

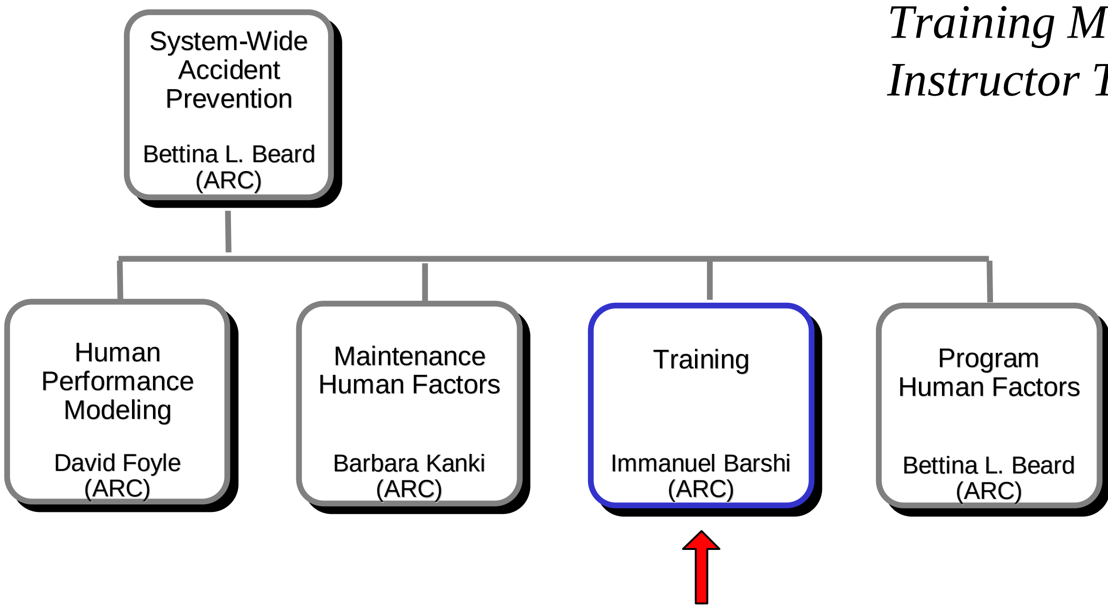
MRM Skills, Training & Evaluation

- GOAL: Recommendations for developing, implementing & measuring the effectiveness of MRM programs
- APPROACH
  - Historical study of industry MRM programs
    - Jim Taylor, Santa Clara University & Manoj Patankar, St Louis University
  - Case study in applied change
    - John Schmidt, Navy Safety Center and Bob Figlock, Naval Postgraduate School

Training Products

Aviation Safety Program — SWAP

Pilot Skill Training for Cockpit Automation
Training Modules and Simulators
Instructor Training & Evaluation



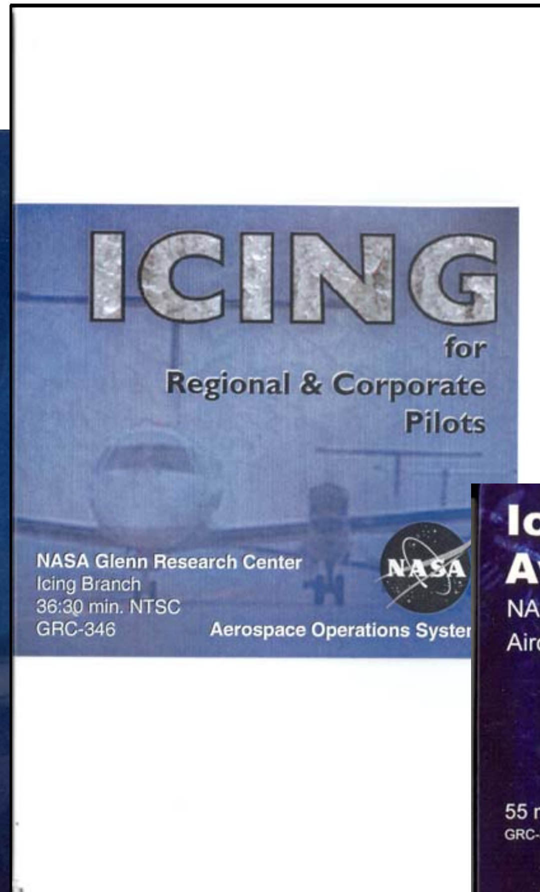
AvSP Training Element Projects

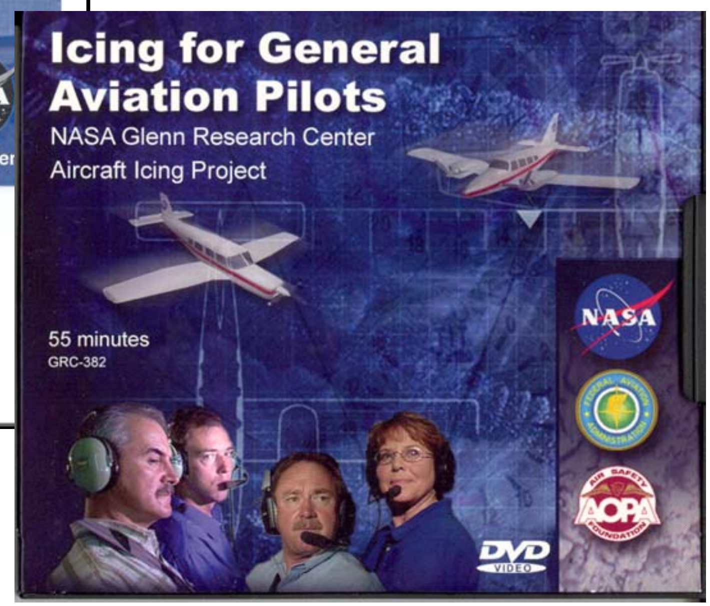
- **NASA Research Announcement Awards:**
  - **Veridian Corporation:** Airplane Upset Training Evaluation
  - **University of Otago:** Learning from Case Histories in General Aviation
  - **San Francisco State University:** Training for Automation Use in Regionals
  - **George Mason University:** Abatement of Automation Errors - Cognitive Model
  - **University of Illinois:** Transfer of Training Effectiveness of Aviation Training Devices
  - **Boeing Corporation:** Analysis of Automation Monitoring Skills

AvSP Training Element Projects, continued

- **NASA Intramural Research and Collaboration:**
  - **Glenn Research Center:**
    - » Pilot Training Simulator for In-flight Icing Encounters
  - **Ames Research Center:**
    - » Ab Initio Cockpit Automation Curriculum
    - » Development of Cockpit Automation Expertise
    - » Gold Standards to Train Instructors to Evaluate Performance
    - » Alertness Management Training Module for GA Pilots
    - » Pilot Weather-Related Decision-Making
    - » Emergency and Abnormal Situations
    - » Low-blood Sugar and Aviation Pilot Performance
    - » Remembering to Complete Interrupted Tasks

Icing Training
with NASA Glenn

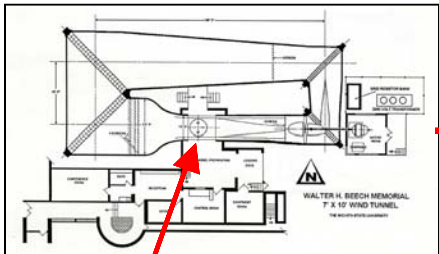




Development of a Pilot Training Flight Simulator for In-flight Icing Encounters

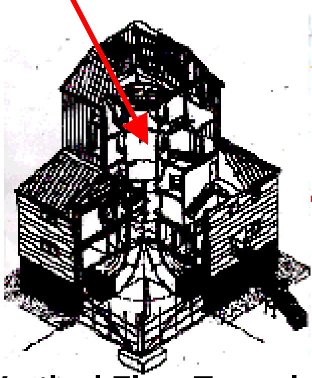
Development Process of an Icing Effects FTD Concept Demonstrator

Low Speed Wind Tunnel



Full-scale Aircraft Flight Test

Sub-scale Complete Aircraft Model



Vertical Flow Tunnel

Aero Effects of Airframe Icing

Verification

Flight Sim Model development & testing

Flight Training Device Demonstrator

Interruption and Distraction Countermeasures

Remembering to Complete Interrupted Tasks

- **Uncompleted procedures:**
  - “Probable cause” of several major
  - accidents (e.g., NW255, Detroit, Aug ‘87)
  - Show up in ASRS reports every month
  - (e.g., failure to set take-off flaps)
- **Interruptions during flows/checklist a major factor in failure to complete actions (Dismukes et al., 1998)**
- **Interruptions especially frequent during pre-start and taxi (Loukopoulos, et al, 2001, 2003)**
- **Laboratory experiments underway:**
  - Why are interrupted tasks not resumed?
  - What factors influence probability of remembering to complete task?
  - What countermeasures would reduce pilots’ vulnerability to interruptions?

Main University Collaborators:

Furman University

University of New Mexico

California Polytechnic State University

Main Industry Collaborators:

Continental Airlines

Southwest Airlines

Automation Training

Low-time, general aviation pilots transitioning to glass cockpit jets … with no automation training or experience.

Main University Collaborators:

University of California - San Diego

Purdue University

Embry Riddle Aeronautical University

Main Industry Collaborators:

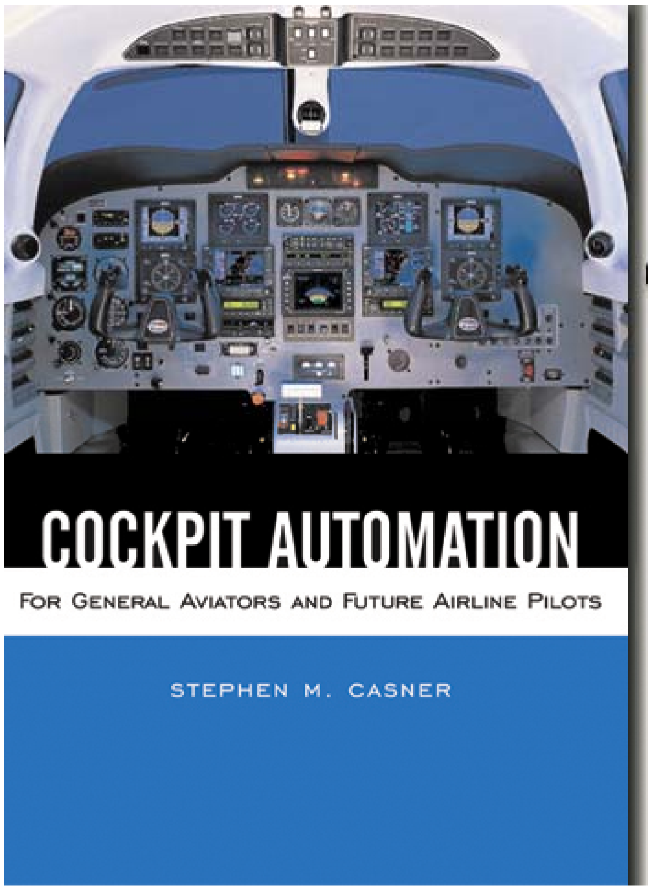
Bel Air Aviation

Sky West

American Flyers

Automation Training

Cockpit Automation Curriculum and Textbook



Teaches fundamentals of cockpit automation use

- Procedures
- Underlying concepts

INSTRUCTIONAL DVD

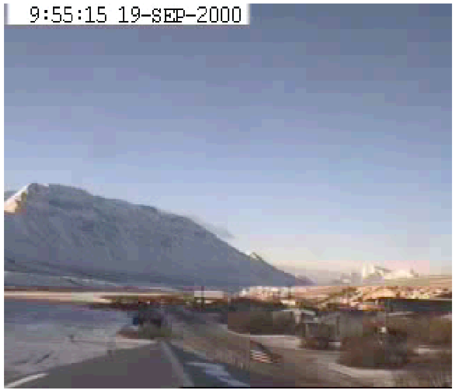
Aviation Weather Decision Making

THE PROBLEM: Bad weather is a major factor in aviation accidents, especially for Pt. 91 and Pt. 135 operations. Alaska weather and terrain are most extreme in the U.S.

Alaska accidents account for 40% of U.S. total.

BACKGROUND

- Focus on Plan Continuation Errors (continuing with original plan in face of changing conditions).
- NTSB (1994) found that #2 contributing factor to fatal accidents was tactical decision errors, most of which involved PCEs.



RESEARCH ISSUES

WHY do pilots enter or continue in bad weather?

- Inadequate weather information
- Contextual factors: Wx, time and economic pressures
- Pilots' risk attitudes and decision strategies

HOW to improve safety of pilot decision making?

Aviation Weather Decision Making

- **Research Strategy**
  - Given that PCEs are associated with aviation accidents, identify patterns of conditions and pilot actions in *incidents* that may be *precursors to accidents*
    - » Identify flight conditions, precipitating events, contextual features, and decisions associated with PCEs
  - Compare Pt. 91 with Pt.135 data
  - Compare Alaska with continental U.S. data
- **Data Sources**
  - ASRS Reports (1994-97) -*"In-flight encounters with weather"*
  - Critical decision interviews and surveys AK pilots (n = 52)

Main University Collaborators:

University of Illinois

University of Alaska - Anchorage

Main Industry Collaborators:

FAA - Capstone Project

NIOSH

Alaska Flight Safety Foundation

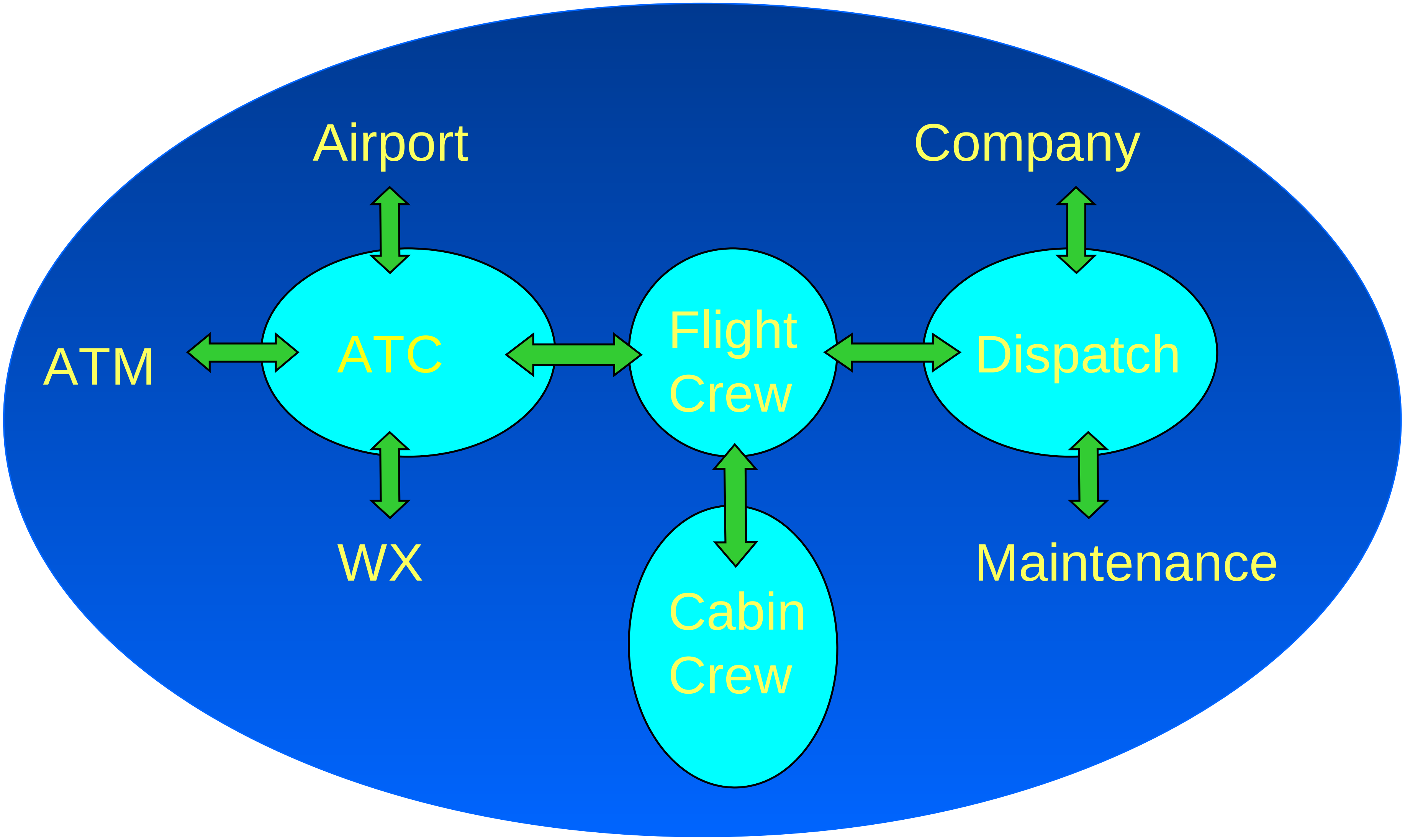
Pilots’ Cognitive Performance and Blood Sugar Level

- ☎ Sugar is the fuel of the brain. We must make sure that the pilots' brains have sufficient fuel for the complex cognitive operations they must perform during flight.

- ☎ It is often difficult for flight crews to eat right during normal line operations.
  - Most airlines no longer provide food for their crews.
  - Crews usually depart in the morning before restaurants open; afternoon crews usually return after restaurants close.
  - Duty days can be long, and quick turn-arounds may not allow sufficient time to find food near the gate.
  - Many airport restaurants are located on the other side of security checkpoints
  - Some pilots complain about reduced performance, headaches, or just hunger. But it's possible that most pilots are adversely affected by this practice even if they are not always aware of it.

- ☎ The purpose of this study is to determine whether or not cognitive performance of pilots in routine line operations is affected by the limited availability of food to the flight crew.

The Emergency Situation



Emergency and Abnormal Situations

A Subset of Industry Contacts and Consultants

- Boeing: Dan Boorman, Bill McKenzie, Dr. Curt Graeber
- Airbus Industries: Michel Tremaud, Jean-Jacques Speyer
- BAE Systems: Captain D.J. Gurney
- FAA: Phyllis Kayten, Steve Boyd, Win Karish, Keeton Zachary
- NTSB: Ben Berman, Nora Marshall, Dr. Robert Molloy
- ALPA: Captain Robert Sumwalt
- ATA: Captain Rick Travers
- TSB of Canada: David Curry, Don Enns, Elizabeth McCullough
- ICAO: Captain Dan Maurino
- CAA (UK): Steve Griffin, Captain Stuart Gruber, Dr. Sue Baker
- Airlines: Southwest Airlines, United Air Lines, Continental Airlines, TWA, Fed Ex, Aloha Airlines, Hawaiian Airlines, Air Canada, Cathay Pacific, Airborne Express, Midwest Express

PHF Products

Human Factors Tools

System-Wide Accident Prevention
Bettina L. Beard (ARC)

- Human Performance Modeling — David Foyle (ARC)
- Maintenance Human Factors — Barbara Kanki (ARC)
- Training — Immanuel Barshi (ARC)
- Program Human Factors — Bettina L. Beard (ARC)

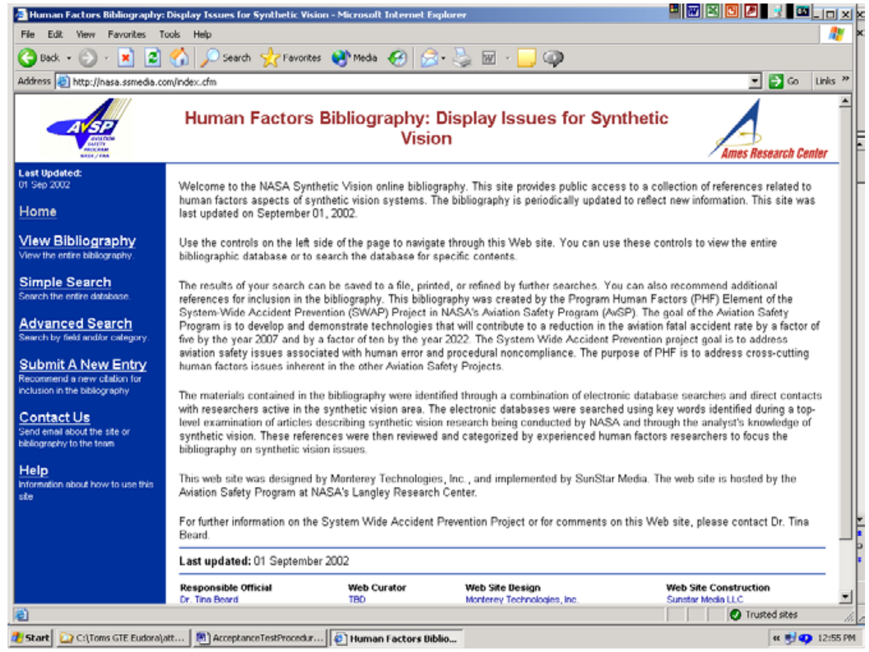
PHF Crew Centered Con Ops

- Many AvSP technologies impact cockpit.
- The crew position is the unifying viewpoint for the benefit of AvSP Program as a whole.
- Notional description of cockpit equipment and procedures from crew viewpoint that assumes presence of technical products of AvSP
- Other developments that will influence character of cockpit and procedures identified.
- Baseline flight task description completed
- Explicit descriptions and scenario showing future character of cockpit and procedures for AvSP technologies.

https://postdoc.arc.nasa.gov/postdoc/t/folder/main.ehtml?url_id=82510

poc: Dr. Robert Hennessy
Monterey Technologies Inc.

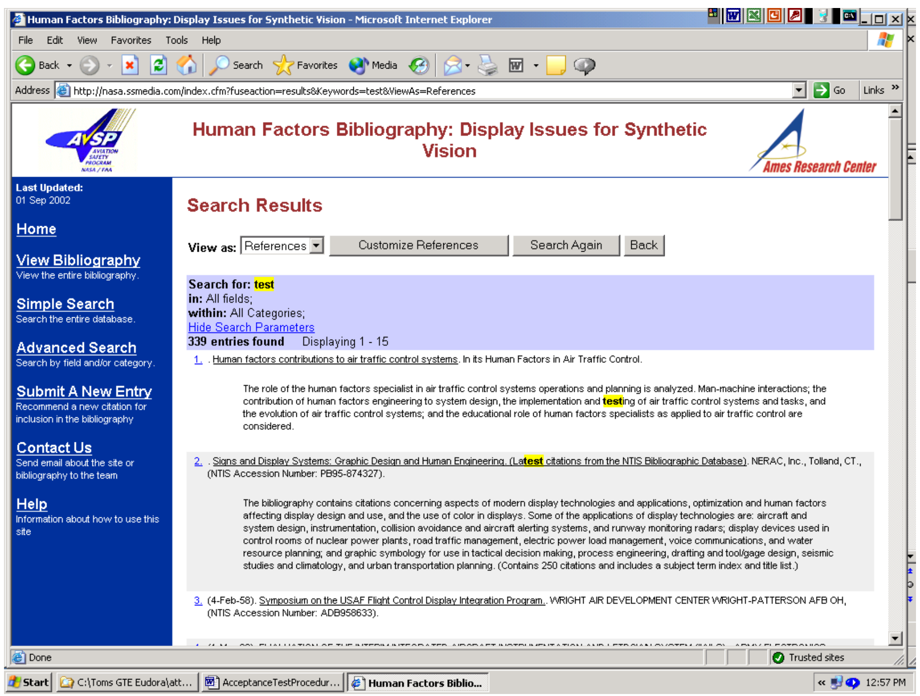
Cockpit Displays Human Factors Website



The website allows the user to:

- View all citations in the bibliography
- Perform simple or advanced searches
- Extract to file or print results
- Submit citations for inclusion
- Contact the curator

http://avsp.larc.nasa.gov/new.html



Features:

- Multiple Search Criteria
- Keyword search
- Variety of formats for results
- Tailorable formats
- Built in online help

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Alert & Warning Integration

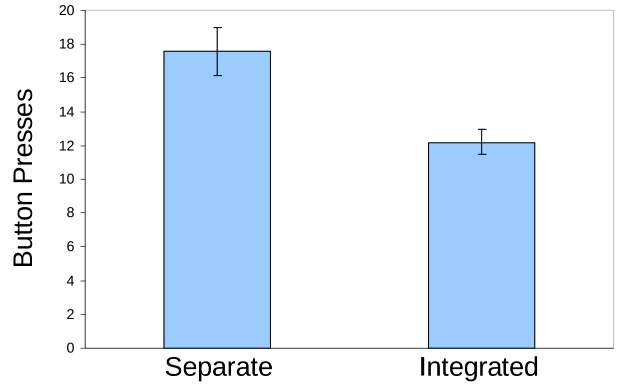
- There is a proliferation of alerting on the flight deck. Current and new systems have separate alerts and notification philosophy for informing the crew.
- The ANCOA (Alerting and Notification of Conditions Outside the Aircraft) program has begun to look at these issues and has demonstrated the integration under a common framework.
- ANCOA provides guidance to how information gets filtered, categorized, prioritized, and represented to the crew.
- Recommend a clear alerting philosophy and notification scheme for the integration information, particularly terrain and weather.
- Generate design specifications
- Implement specifications in software
- Review integrated system with expert pilots

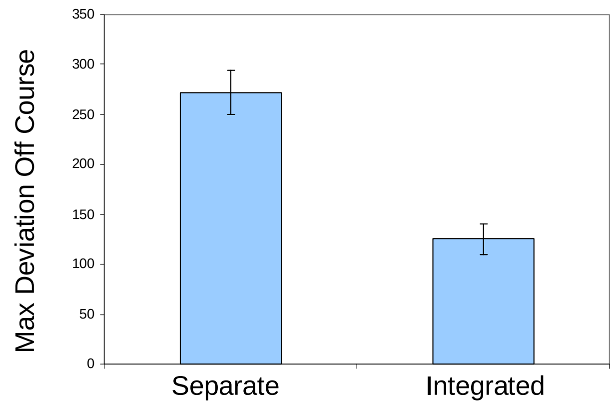
poc: Dr. Trish Ververs
Honeywell Technologies

Terrain/Traffic/Wx Integration

Research Findings

Integrated Alerting System prototype indicating overlay of weather, terrain, and traffic on a single display





Data supports the integration of currently disparate systems onto a single display with performance requiring fewer pilot inputs and lower workload scores

POC: Dr. Trish Ververs
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Tech transfer to industry underway, e.g.:

- Alertness management module for GA posted on Web
- Icing videos, CBT, DVD
- Cockpit automation for general aviation and future airline pilots textbook
- Boeing analysis of automation monitoring skills
- Gold standards to train instructors to evaluate crew performance
- Evaluation of airplane upset training
- Guidelines for the integration of alerts in the cockpit
- MRM tools and guidance
- HFACS-ME data analysis tool for maintenance
- Risk assessment and ROI tools for maintenance

PHF HF Issues Document & Prioritization

Aviation Safety Program **SWAP**

Human Factors Issues

SvS Concerns

		Predictor or Velocity Vector	Photorealistic Terrain	Wireframe terrain	Egocentric 3-D View
Workload					
	Mental demand	Ref: 1.2.1.1 Predictor workload not as high as FMA	Ref. 1.1.5.3 terrain provided spatial awareness - 1.1.7.2 Terrain improved SA, not performance - 1.1.8.4 Terrain slope perception - 1.1.5.4 Landing flare strategies	Ref. 1.1.5.3 terrain provided spatial awareness - 1.1.7.2 Terrain improved SA, not performance - 1.1.8.4 Terrain slope perception - 1.1.5.4 Landing flare strategies	Ref: 1.1.1.1 Low cognitive integration - 1.1.8.5 High mental proximity - 1.1.5.4 Flare strategy
	Physical demand	N/A	Ref: Long delays & sickness 1.1.2.2	Ref: 1.1.2.2 Long delays & sickness	Ref: 1.1.1.1 No cost of visual scanning
	Temporal demand	Ref: 1.2.1.1 Predictor workload not as high as FMA	**Not tested**	**Not tested**	Ref: 1.1.1.1 Low cognitive integration cost, but keyhole effect- 1.2.3.2 Few visual cues for distance to tunnel - 1.1.5.4 Flare strategy
	Performance	Ref: 1.2.1.1 Predictor not as accurate as FMA - 1.1.5.3 altitude judgement	**Ref: 1.1.7.2 Terrain improved SA, not performance - 1.1.5.4 Landing flare - 1.1.5.2 Telepresence and performance - 1.1.5.3 Improved altitude judgements**	**Ref: 1.1.7.2 Terrain improved SA, not performance - 1.1.5.4 Landing flare - 1.1.5.2 Telepresence and performance - 1.1.5.3 Improved altitude judgements - 1.1.5.4 Perception & Density**	Ref: 1.2.1.1 pathway acquisition accuracy- 1.1.1.1 Better orientation than distance judgements
Situation Awareness	current situation ownship systems	**Not tested**	**Not tested**	**Not tested**	**Ref: 1.2.3.2 Better trend tracking needed**
	current situation-geographic	Ref: 1.1.6.3 Guidance symbology - 1.2.3.3 SA improved	Ref: 1.2.3.3, 1.2.3.5 Improved SA - 1.1.5.4 Landing flare	Ref: 1.2.3.3, 1.2.3.5 Improved SA - 1.1.5.4 Landing flare	Ref: 1.1.1.1 Depth ambiguity, better orientation judgements - 1.1.5.1 Reduced global SA - 1.2.3.3 Improved SA, representative of terrain outside
	current situation-environmental				Ref: 1.2.3.2 Task complexity more powerful on ability to focus outside of cockpit than displayÕs novelty - 1.2.3.3 Relative position SA improved
	current situation-spatial/temporal				Ref: 1.2.3.2, 1.2.3.3 Good spatial awareness, Awareness of secondary info on display questionable, Most wanted 2-D Nav + 3-D tunnel display
	Projection/ prediction	Ref: 1.2.3.6 Rejoining pathway - 1.1.6.3 Guidance symbology	Ref: 1.2.3.6 Projection improved - 1.1.7.2 Terrain improved SA, but not performance	Ref: 1.2.3.6 Projection improved - 1.1.7.2 Terrain improved SA, but not performance	Ref: 1.2.3.3, 1.2.3.6 Rejoining pathway
Appropriate Feedback					
Operating Feedback		Ref: 1.1.6.3 direction indication & preview - 1.2.6.2 current nav error	Ref: 1.1.5.1 Terrain improves global SA - 1.1.5.4 Landing flare strategies	Ref: 1.1.5.1 Terrain improves global SA - 1.1.5.4 Landing flare strategies	Ref: 1.1.1.1 Keyhole effect, visual momentum w/ OTW - 1.1.5.1 Reduced global SA
	Modal Feedback for Operating	Visual	Visual	Visual	Visual
	Failed Mode Feedback	**Nothing currently exists**	**Nothing currently exists**	**Nothing currently exists**	**Nothing currently exists**
	Alerts	**Nothing currently exists**	**Nothing currently exists for a single SVS display**	**Nothing currently exists for a single SVS display**	**Nothing currently exists**
	number				
	levels of meaning				
	modalities used				

PHF HF Issues Document & Prioritization

Human Factors Issues

WxAP Concerns

		AWARE	GWIS	AWE	ANCOA	Other Studies
		Aviation Weather Analysis and Reporting Enhancements	Graphical Wx Inforamtion System	Aviation Wx data visualization Environement	Alerting and Notification of Conditions Outside the Aircraft	
		Ruokangas -NASAá Rockwell Collins	Scanlon -NASA	Spirkovska & Lodha- NASA	Ververs, Dorneich, Good, Rye, Downs, Niehus, & Dewing - Honeywell	
Workload						
	Mental Demand		6.5.3 Wx monitoring should be automated, provide indication according to their importance.		6.3.1 Separate display had a higher workload than an integrated display.	6.6.2 status displays may be preferable to command displays as they yield more robust performance benefits and appear less vulnerable to automation biases
			6.5.6. Provide automatic reorientation or interface control to point the aircraft symbol up allowing the pilot to change to a track up position when showing information.		6.5.3 Pilots may not know when/what to request for wx information.	
					6.4.2 Integration display increased time to react than with a separate display.	
	Physical Demand		6.6.2 Excessive menu navigation frustrate pilots.			
	Temporal Demand					
	Performance	Preformance increased compared to DUATs	6.5.1 Reduced reliance on ground based wx sources.		6.3.1 Performance increased with a single alert without having to mentally integrate	6.5.1 Not all pilots know the value of getting wx trend information.
						6.5.2 Less reliance on automation, with status displays tha command displays.
Situation Awareness						
	current situation ownship systems		6.5.1 Subject didn't understand location of wx relative to position of aircraft.	6.8.2 Wanted a visual reference of what airport is being reported.		6.8.2 Pilot had trouble identifying location of aircraft withou an ownship icon. SA increased with ownship icon
	current situation-geographic		6.4.6 Map orientation should be track up configeration otherwise, mental rotation	6.4.2 VFR chart background easily helps identify where they are.		6.4.2 SA increased when spacially related databases on integrated display.
						6.5.3 Display should alert pilot that situation has changed.
	current situation of weather		6.5.1 Trend inforamation and location of wx increased SA			6.5.1 Provided wx trends to improve SA
	current situatio n- spatial/temporal					6.4.5 Info on spacial location is more important than severi of hazard.
	Projection/ Forecasting			6.5.1 Automatic TAF didn't show forcast for all airports/timeframe only. Selected airport based on arrive time		6.7.1 Lack of SA due to lack of experience and general wx conditions.
						6.2 Verbal and written reports of weather conditions are simply not sensitive enough to discriminate between differences that exist across experience levels
Appropriate Feedback						
Operating Feedback				Provides alternative route selection.		
	Modal Feedback for Operating	Visual		Visual	6.4.5.2 Time critical - Synthetic voice. Tactical & strategic earcon.	